MOTOROLA

June 20, 2003

James D. Schlichting
Deputy Chief
Office of Engineering and Technology
445 12th St. S.W.
Washington DC 20554

Re: WT Docket 02-55

Dear Mr. Schlichting,

Motorola provides this information in response to questions raised at the May 29, 2003 industry-wide meeting with the FCC and your letter dated June 3, 2003. Questions raised at the meeting include the need to provide additional information on the costs of addressing interference in the 800 MHz band and on the effectiveness of resolving interference through a technical approach. In your letter you specifically request information on the assumptions used in our May 6th filing to determine that a public safety system meets a 95% reliability design requirement.

Motorola appreciates the opportunity to provide greater clarity regarding the resolution of interference in the 800 MHz band based on the technical advances presented in our May 6 letter. Motorola would like to assure the Commission that it is dedicated to implementing this advanced technology in all of its future 800 MHz portable radios regardless of any policy decisions made as to the future configuration of users in this band. The technical toolbox presented in our May 6 letter can mitigate interference in the 800 MHz band and all of the tools in this box will be required regardless of the ultimate configuration of users in this band, particularly as technologies and uses of the band continue to evolve.

THE TECHNICAL TOOLBOX FOR ADRESSING INTERFERENCE

In its letter of May 6, 2003, Motorola described progress that it has made on developing advanced receivers for use in the 800 MHz band to mitigate interference. These receivers use attenuation to provide increased immunity to intermodulation interference and overload interference.[1] Motorola also discussed the need for proactive methods to attempt to identify areas of potential interference before they occur so that appropriate preventative actions can be taken. Best practices includes a wide range of actions, including, but not limited to filtering emissions, modifying antenna patterns to reduce signal strength on the ground, changing frequencies at a specific location, adjusting

[1] The attenuation can be implemented either through a software-controlled switchable attenuator or by detuning a tunable varactor filter currently included in some model radios.

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relative signal strengths, and improving receiver performance. As stated in our May 6 letter, taken together, advanced technology and best practices provide a technical toolbox for mitigating interference.

Various parties have been working to fully understand the interference mechanisms at work in the 800 MHz band and to develop solutions since 1999 when interference first began to appear This effort has been greatly advanced by the work of the consensus parties, which contributed significantly to identifying interference and to developing the solutions for addressing the interference. As stated in our May 6 letter, "Nextel, working with associations that represent public safety and private radio interests, has developed a plan ("Consensus Plan"), which would significantly reduce interference in the 800 MHz band by consolidating public safety use and eliminating the interleaving of CMRS channels with public safety."[2] This would create a friendlier interference environment.[3] The Consensus Parties have also provided important details in their proposal for revised best practices as to what is necessary and reasonable to address interference when it happens. This includes ensuring that equipment and systems in the 800 MHz band are designed and deployed to the highest standards, which will help ensure a reliable and interference-free 800 MHz environment. Resolving interference in this band as quickly and effectively as possible is critical to the reliability of public safety and other critical infrastructure systems.

As discussed in our May 6th letter, there are three basic interference mechanisms manifested in the 800 MHz band, 1) intermodulation interference, 2) overload interference, and 3) interference from out-of-band emissions. As described below, the technical toolbox addresses these interference mechanisms.

Intermodulation Interference

Intermodulation interference occurs when two of more frequencies combine to create a new frequency of sufficient strength that is the same as the desired signal that a public safety or other user is trying to receive. In the 800 MHz band, intermodulation interference is predominately third order mixing products ($2f_1$-f_2 or f_1+f_2-f_3), however it can also be fifth order mixing products ($3f_1$-$2f_2$ or f_1+f_2+f_3-f_4-f_5).

The advanced receiver technology developed by Motorola, which attenuates signals into the front end of a radio, significantly mitigates intermodulation interference by providing a 3 to 1 (third order) or 5 to 1 (fifth order) reduction in interfering signal versus the desired signal. Accordingly, for every decibel that the attenuator reduces the desired signal, there is a three-decibel reduction in the third order interfering signal, providing a 2 dB net benefit, or a five-decibel reduction in the fifth order interfering signal providing a 4 dB net benefit. Radios using the attenuator solution achieve intermodulation rejection performance that exceeds the performance of current 800 MHz mobile

[2] *See* May 6, 2003 letter from Steve Sharkey to Edmond Thomas, at 2.

[3] See discussion on mitigation of out-of-band interference at 3, *infra*.

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receivers that meet TIA class A specifications. Motorola is not aware of any intermodulation interference being reported for the current 800 MHz mobile units meeting TIA class A specifications.

Overload Interference/Receiver Blocking

Receiver overload can be defined as very strong off-channel signals that can force undesired energy past frequency selective elements in a receiver to cause limiters or automatic gain control (AGC) circuits to be activated. This reduces the available gain for the desired signal resulting in a loss of sensitivity.

Receiver blocking can be defined as a receiver front end being overloaded by a single high-level unwanted signal, not on the desired channel, typically in excess of -25 dBm, or multiple high-level unwanted signals whose total peak instantaneous power exceeds -25 dBm.

The advanced receiver technology developed by Motorola will mitigate both receiver overload and blocking interference cases by attenuating strong signals on channel and off-channel by 15 dB. This level of attenuation will help mitigate cases of receiver overload /blocking by reducing undesired signals such that the receiver limiter or AGC circuits are not overdriven. Additional best practices can be used in combination with the switchable attenuator to resolve cases where receiver overload or blocking occurs.

Interference from Out-of-Band Emissions

Interference from out-of-band emissions (OOBE) can potentially result when off-channel signals create energy on frequencies other than the intended channel. Such off-channel signals are a natural by-product of amplifying radio signals. While the level of sideband energy is generally reduced to below that allowed by regulation, it may still be sufficient to create interference in areas where sufficiently low desired signal strengths occur near low CMRS sites where sufficiently strong OOBE signals are not otherwise attenuated.[4] In such cases it is necessary to adjust the relative strengths of the desired and undesired signal by either 1) reducing the undesired OOBE, or 2) increasing the desired signal. Reducing the relative difference (increasing C/I) to acceptable levels will resolve OOBE interference. Notifying frequency coordinators prior to implementation of low site antennas would enable interference to be addressed in a pro-active manner. The most appropriate approach to addressing OOBE will depend on the specific circumstances experienced.

1) ***Reducing OOBE signals*** **–** As discussed in our May 29th presentation, there are a number of methods to reduce the OOBE signal level. External filtering is often added to transmitters to reduce OOBE signal levels. The OOBE signal level can also be reduced by reducing the CMRS transmit power, or by modifying antenna patterns in order to limit signal strength on the ground. Another effective

[4] A certain signal to interference plus noise ratio (C/(I+N)) is required for a radio to operate properly. It is only when the undesired OOBE signal results in a rise in noise floor that degrades the desired signal level below the minimum required C/(I+N) that interference will occur due to OOBE.

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method of reducing OOBE signals is by maximizing the frequency separation between the desired signal and the source of the undesired OOBE by minimizing frequency interleaving of high-site and low-site systems to provide greater frequency separation between weak desired signals and strong undesired signals. Finally, the antenna height of a CMRS site can be increased to provide greater path loss.

2) *Increasing Desired Signal* - As part of best practices, some steps can also be taken by the user receiving interference to increase the desired signal relative to the undesired signal strength. It may be possible to increase the signal strength of the desired signal by increasing effective radiated power in the area of interference, either by increasing transmitter power or by using directional antennas. As discussed above, providing greater frequency separation, potentially through swapping frequencies with CMRS providers, between the weak desired signal and a stronger undesired signal will increase the ratio of desired to undesired power. Finally, additional transmitter sites can be added in an area of interference to increase the local signal strength.

PUBLIC SAFETY RELIABILITY

In your June 3rd letter you specifically ask for the assumptions and analysis underlying the statement, "[a] radio with IM performance of 75 dB and a switchable attenuator that turns on 10 dB of attenuation when the desired signal level is greater than -99 dBm, indicates that potentially interfering CMRS sites within approximately 12 miles will allow the public safety users to achieve the 95% coverage criteria," referenced in Motorola's *ex parte* presentation of May 6, 2003. This statement is based on Figure 1 of that submission, which is reproduced below. Figure 1 shows public safety outage level around a CMRS site as a function of the distance between the public safety site and a potentially interfering CMRS site. Figure 1 clearly shows that the reliability of a public safety system is greatly increased by adding the switchable attenuator to a receiver, by showing that the 95% reliability requirement is met over a much wider range of conditions by a receiver with the attenuator than without.

The performance level of a receiver is determined by its "IMR", which is an intermodulation rejection specification defined by the TIA-102CAAA standard, and the amount of front-end attenuation added and the signal strength at which the attenuation is added.

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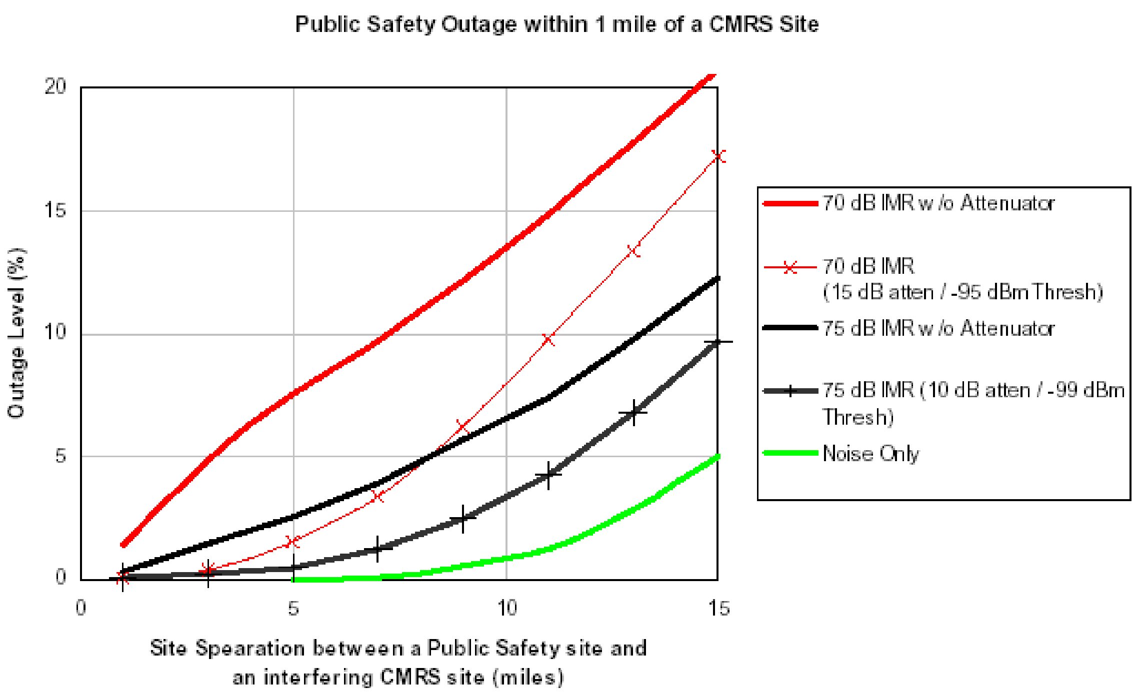

Figure 1

The graph in Figure 1 was created using a model of the land mobile radio environment. The model is a tool to help visualize and quantify the impact of intermodulation interference and mitigation strategies. It is not intended to be a system design tool and does not reflect the coverage encountered at a specific site. The model is based on the assumption that 95% reliability is achieved at a range of 15 miles from the public safety site in the thermal noise-only environment. This is a typical suburban environment range, but in practice can vary widely depending on conditions.

The outage level given in the graph is the percentage of locations within a one mile square centered on the CMRS site that have a signal to noise ratio (SNR) of less than 16.5 dB. The 16.5 dB SNR results in a minimally acceptable audio quality for an APCO Project 25 system per TIA TSB88.[5] Also, the noise figure and noise equivalent bandwidth of the APCO 25 receiver were assumed to be 10 dB and 5.76 kHz, respectively, which results in a receiver noise floor about –126.5 dBm, which is a typical design specification. The locations referred to above are laid out on a grid around the CMRS site with the points on the grid being 100' apart, consequently, there are 11,449 points in the grid.

The signal strength of the public safety and CMRS signals at each point on the grid are calculated based on their distance from their respective sites and a random component drawn from a normal distribution. The distance-dependant component of the public safety signal strength is based on

[5] It should be noted that different users might design systems to operate with signal to noise ratio different than what is used here. While this would change the distance at which 95% reliability is achieved, all of the graph results would shift, including the base line, and the overall improvement in reliability would be consistent.

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a simple power-law model and the random component has a standard deviation of 8 dB. The signal strength of the CMRS site was determined using a model developed in 1999 when the interference issue first became known. We measured the signal strength around 17 Nextel sites in the Chicago area and developed a signal strength model (as opposed to a path loss model) with range dependant and random components.[6]

The CMRS signal strength is applied to a third-order intermodulation model. In this model the power of the intermodulation product is given by:

$$P_{IM} = 3(P_u) + k \qquad (1)$$

where P_{IM} is the power of the intermodulation product in dBm, P_u is the power of each of the two signals that are generating the intermodulation product in dBm and k is a constant determined by intermodulation specification of the receiver.

TIA standard TIA-102CAAA defines InterModulation Rejection (IMR) using a test procedure. In the procedure, an RF signal that produces 5% bit error rate (BER) in the receiver is increased 3 dB. Then two RF signals that produce a 2A-B IM component on the desired channel are increased in strength until 5% BER is obtained again. The IMR is the difference between the power level that produces 5% BER without interference and the power level of the interfering signals that cause the BER to be increased back to 5%. Understanding this, the formula above can be populated to solve for k as follows:

$$P_{IM} = P_n = 3(P_n + SNR_{5\%BER} + IMR) + k \;; \quad k = P_n - 3(P_n + SNR_{5\%BER} + IMR) \qquad (2)$$

where P_n is the thermal noise floor of the receiver, $SNR_{5\%BER}$ is the SNR required for 5% BER and the IMR is the IMR specification measured as described above. We know from our work with Astro products that P_n is about –126.5 dBm and $SNR_{5\%BER}$ is about 6.5 dB. Therefore, the value of *k* for a 70 dB IMR radio is 23.5 dB.

The signal level determined for the CMRS signal at a given location is substituted for P_u in formula (1). This gives the power of the intermodulation interference on the public safety channel. The interference power is added to the public safety signal level and the thermal noise floor of the receiver to determine the signal strength detected by the public safety receiver. If this signal strength is above a threshold value (-99 dBm in the statement above) the public safety and CMRS signals are reduced by an attenuation value (10 dB in the statement above) and the intermodulation interference power is recalculated and added to the thermal noise power. This value is subtracted from the new public safety signal level to determine the signal to noise ratio of the public safety signal. If the signal strength detected by the public safety receiver does not exceed the threshold the signals are not attenuated before calculating the signal to noise ratio.

[6] While the exact curves would vary somewhat depending on sites selected and measurements used, the relative improvement in performance as a result of increased IMR and the attenuator would be consistent.

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If the signal to noise ratio exceeds the required level (16.5 dB was assumed, as mentioned above) the location is considered free from interference. If the signal to noise falls below the threshold it is considered to suffer from interference. The graph was generated using this model at various site separations, receiver IMR levels, attenuation thresholds and attenuation levels.

We note that this model is conservative. Results from field tests have shown less interference than that predicted by this model. Accordingly, systems designed in accordance with this model to the 95% reliability target assumed in our discussion will exhibit greater reliability in practice.

IMPLEMENTING ATTENUATOR TECHNOLOGY

Some questions have been raised about the costs of implementing attenuators and the need to replace a large number of portable radios or increase signal coverage prior to using an attenuator. In our May 6 letter, we stated that the switchable attenuator could only be used in areas where there was sufficient desired signal strength on the order of -98 dBm to –95 dBm. Some parties' question whether this means that users would have to significantly upgrade their systems to meet the minimum requirements.[7]

As addressed at the May 29th FCC meeting, Motorola does not anticipate significant changes in the operation of 800 MHz public safety or private radio systems to allow users to take advantage of the advanced receiver technology. Systems designed for portable radio coverage should already meet the minimum threshold value necessary for use of the switchable attenuator. In general, it should only be in the limited number of cases where a system is designed for mobile, not portable coverage, but where portable radios are being used *and* where CMRS signals are sufficiently strong near low sites, where the desired signal may have to be increased to a level appropriate for reliable portable radio use. As discussed more below, no increase or change in desired signal strength was necessary in the areas where Motorola has conducted testing and the solution has worked.

Questions have also been raised regarding the cost of deploying advanced technology portable radios. Motorola anticipates having the technology available in several ways.

First, Motorola plans to include the switchable attenuator technology in all of its future 800 MHz radios, with a target of year-end to begin commercial implementation. Motorola does not anticipate any incremental increase in the cost of radios as a result of adding this technology. Accordingly, since the large majority of users are not experiencing interference, the technology will be deployed as part of the normal radio turnover for users. Thus there will be no additional cost in this case. This is also a proactive approach to attacking interference by improving the overall 800 MHz interference environment.

[7] *See* letter from National Association of Manufacturers (NAM) and MRFAC to Secretary, Federal Communications Commission, dated May 29, 2003.

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Second, interference immunity comparable to that achieved by the switchable attenuator can be obtained by detuning the tunable varactor filters that are part of the dual band 700/800 MHz XTS2500 and XTS5000 model radios, which have been shipping since 4th Quarter 2001. Motorola intends to make software available to implement this solution at no cost to those customers that have purchased these radios. Motorola will work with individual customers to determine whether it is desirable to upgrade the radio software specifically for this purpose or whether the software will be included with a customer's software upgrade to add other features.

Third, Motorola plans on making retrofit kits for some models of radios that have sufficient processing power and memory. These models include the MTS2000, XTS3000, and ASTRO Saber radios. These models account for some 70% of sales over the past 10 years. While the final cost of a retrofit is not known, Motorola anticipates that, the hardware cost will be approximately $300. Retrofitting existing radios will only be necessary in the very limited number of cases where interference is being experienced and the interference cannot be mitigated through other best practices.

Because the technical toolbox will be applied in various ways depending on specific individual circumstances, it is difficult to provide a dollar estimate for resolving the interference. While licensees are currently incurring costs to mitigate interference using many of the best practices described herein, in order to be fully effective, it will be necessary to apply the technical toolbox more aggressively and proactively than best practices have been in the past. Accordingly, Motorola expects that there will be some incremental increase in the cost of mitigating interference compared to the costs that are incurred currently.

UPDATE ON TESTING

In addition to the testing discussed in our May 6 letter, the following update on testing is provided.

Multiple data samples were taken across nine different sites in Las Vegas and San Diego. Of the nine sites tested, all sites were found to have 3rd order intermodulation or other non-linear responses such as receiver overload. The use of the front-end attenuator mitigated the interference caused by intermodulation and overload. We identified one site where the front-end attenuator provided 50% improved performance, however the site appeared to have an OOBE floor that would require application of the best practices discussed to provide additional interference mitigation. In all cases the existing desired signal strength exceeded the threshold signal necessary for use of the attenuator.

Las Vegas (Southern Nevada Area Communication Council – SNACC)

The table below describes the results found at the five sites surveyed. It was discovered that the intermodulation products for the interference could not always be calculated and at some sites all channels were affected. The interference mechanism could be intermodulation (3rd or 5th order) or receiver overload. Therefore, the term "non-linearity" was used to describe the interference mechanism

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if the attenuator mitigated the interference. The interference in all these areas was severe enough that the MTS2000 radio could not receive the trunking control channel and would deny the service request on PTT. In all cases the use of the attenuator was found to be effective in mitigating the interference.

SNACC Site	Interf. Area (Sq Ft)	Total RF Power (800 MHz qtr wave)	RF Power 851-869 MHz	Public Safety Signal Strength (25 kHz)	Interference Mechanism	Attenuator Effective-ness
LV Convention Center East Dock	300K	-12.1dBm	-14.1dBm	-87 to -71dBm	Non-Linearity	100%
Church at Robindale and Green Valley	35K	-18.0dBm	-18.9dBm	-84dBm to -75dBm	Non-Linearity	100%
Ramrod Road	65K	-13.3dBm	-14.4dBm		Non-Linearity	100%
Wells St & Palm Dr, Henderson	25K			-97dBm to – 87dBm	Non-Linearity	100%
Green Valley Rd & Legacy Dr, Henderson	<10K	-21.1dBm	-33.5dBm		Non-Linearity	100%

City of San Diego

The table below summarizes the results found at four interference sites surveyed. The interference in these areas was severe enough that the MTS2000 radio could not reliably receive the trunking control channel. The worst case site was at Mission Bay and Garnet also known as the World Gym Site. It is a very dense site with five cellular operators co-located. The attenuator feature in the XTS5000 portable provided approximately 50% improvement. With the support of Nextel, several experiments identified that OOBE was the probable cause of the remaining outages at this site when 3 or more Nextel channels were active. In this case best practices would need to be applied to resolve the remaining interference. At all other sites the attenuator was effective in mitigating the interference.

The Highway 52 and Interstate 5 site provided a unique opportunity to test how the attenuator technology would work in a mobility scenario. This site, which has two carriers, is constructed with the antennas mounted under the roadway surface on the sides on the cast concrete elevated roadway structure. The interchange provides access to/from HWY 52 (E-W) and I-5 (N-S). The antennas are mounted on access ramps that are approximately 50 to 70 feet above the ground. Traversing the interchange from all directions, it was found that when east bound on Hwy 52 the vehicle would pass through the line of site of one antenna array at about 25-50 ft horizontally displaced. As the vehicle was moving west to east, at approximately 40-60 mph the control channel would be muted for about 1 - 2 seconds when the XTS5000 was operated in the standard mode. Simultaneously a second XTS5000 radio was operated with the attenuator feature mode enabled. There were no instances of the control channel not being received on this modified radio.

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City of San Diego Site	Interf. Area (Sq Ft)	Total RF Power (800 MHz qtr wave)	RF Power 851-869 MHz	Public Safety Signal Strength (25 kHz)	Interference Mechanism	Attenuator Effective-ness
Mission Bay and Garnet	160K	-10.3dBm	-12.6Bm	-95dBm to -85dBm	Non-Linearity and OOBE	50%
Ingraham between Grand & Garnett	<10K				Non-Linearity	100%
4665 Cass St.	<10K	-20.4dBm	-21.4dBm	-76dBm	Non-Linearity	100%
Junction of I-5 & CA-52	<10K				Non-Linearity	100%

Motorola appreciates this opportunity to provide additional information to the record of this proceeding. Please feel free to contact the undersigned if you have questions or require additional information.

Sincerely,

________/S/________________

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